Theme 2: Modeling, Data Assimilation and Advanced Computing

Stephen S. Weygandt

Data Assimilation and Rapid Cycling Numerical Weather Prediction

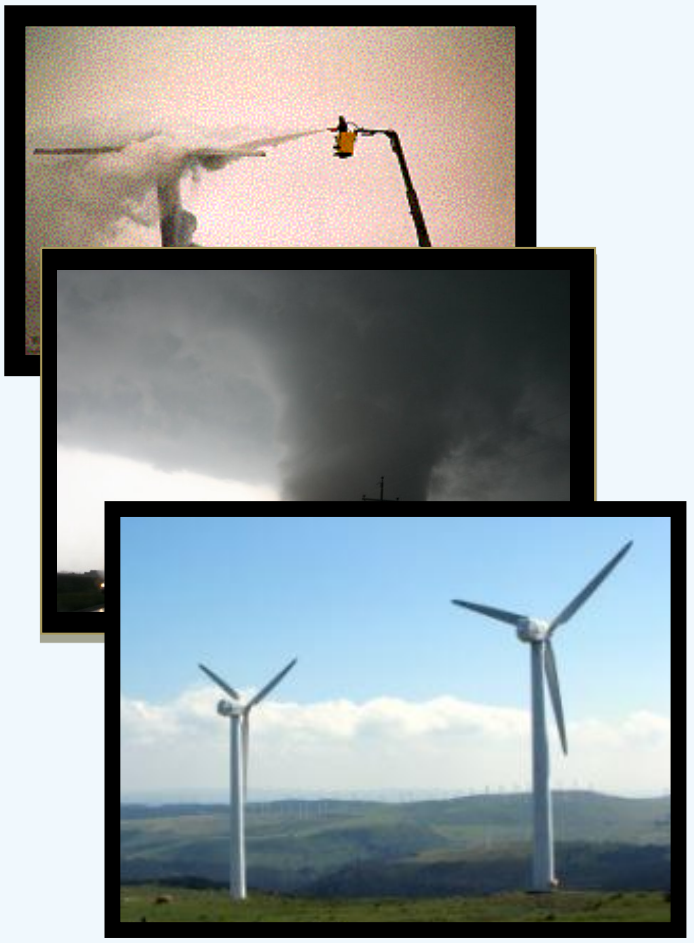
Data Assimilation and Rapid Cycling Numerical Weather Prediction

Detailed, precise short-range weather guidance needed for:

Air transportation (NextGen)

Severe weather (Warn-on-Forecast)

Renewable energy



Data Assimilation and Rapid Cycling Numerical Weather Prediction

Detailed, precise short-range weather guidance needed for:

Air transportation (NextGen)

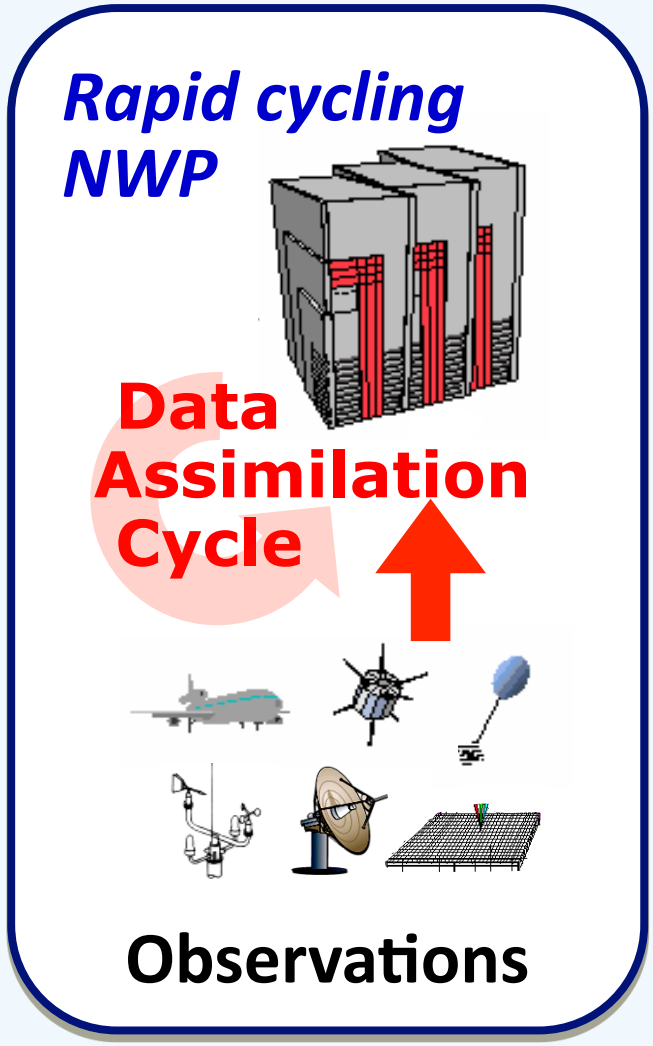
Severe weather (Warn-on-Forecast)

Renewable energy

Requires continuing advances in:

Rapid cycling numerical weather prediction (NWP)

Advanced data assimilation (DA)



Rapid Cycling NWP at ESRL

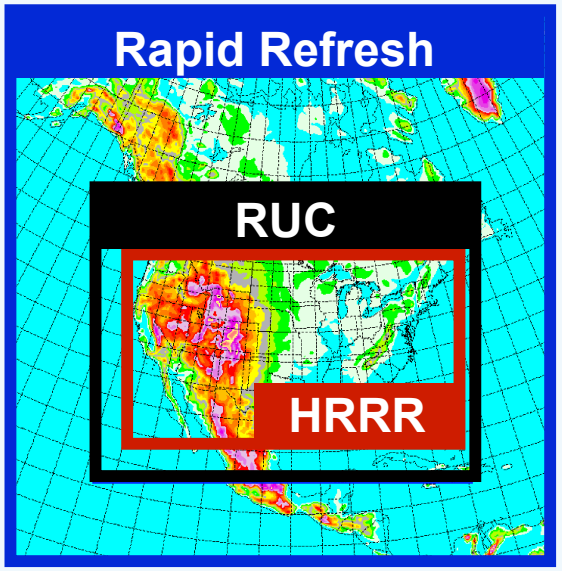
Pioneering work on rapid cycling forecast systems and thunderstorm prediction

Rapid Update Cycle (RUC)

- *First NCEP hourly cycling model*
- *First NCEP reflectivity assimilation*

Rapid Refresh (RR)

- *First North American hourly cycling*
- *Community codes (GSI, WRF ARW)*



High-Resolution Rapid Refresh (HRRR)

- *First hourly updated CONUS storm-scale model*
- *Assimilation (including radar data) from RUC/RR*

Data Assimilation at ESRL

Expertise in the development and application of innovative data assimilation techniques

Local: ***Local Analysis and Prediction System (LAPS)***
Space-Time Mesoscale Analysis System (STMAS)

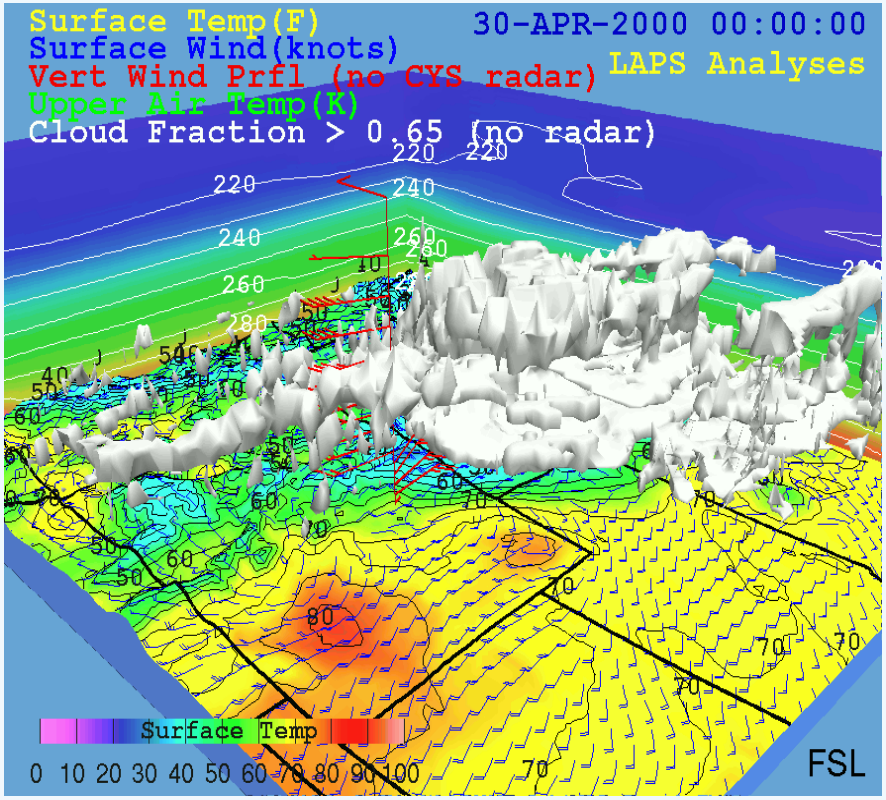
Regional: ***Rapid Update Cycle (RUC) 3DVAR***
Rapid Refresh (RR) GSI 3DVAR
Cloud / hydrometeor analysis
Radar reflectivity assimilation

Data Assimilation Cycle

Global: ***Ensemble Kalman filter assimilation***

Local Analysis and Prediction System

Highly portable analysis / forecast system with unique assimilation features



Successive correction method, multiple observation types

Detailed cloud type analysis using satellite and radar data

Balance equation adjustment including diabatic effects

Provides consistent analyses, can use to initialize models

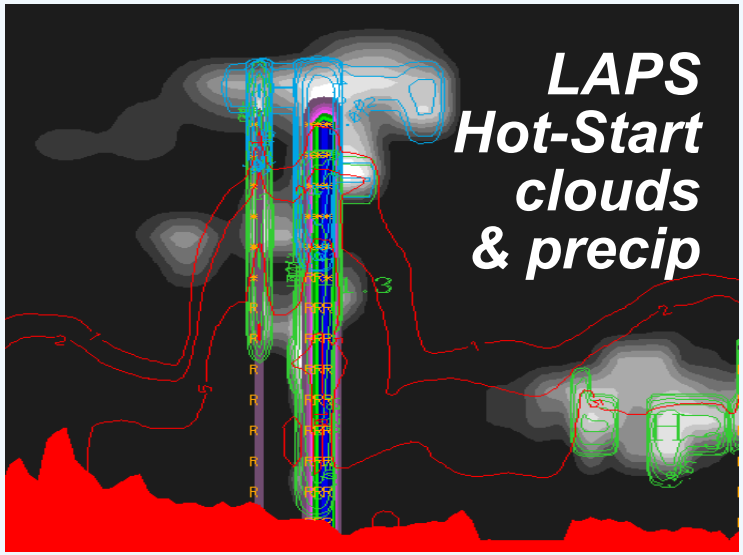
LAPS Usage and Plans

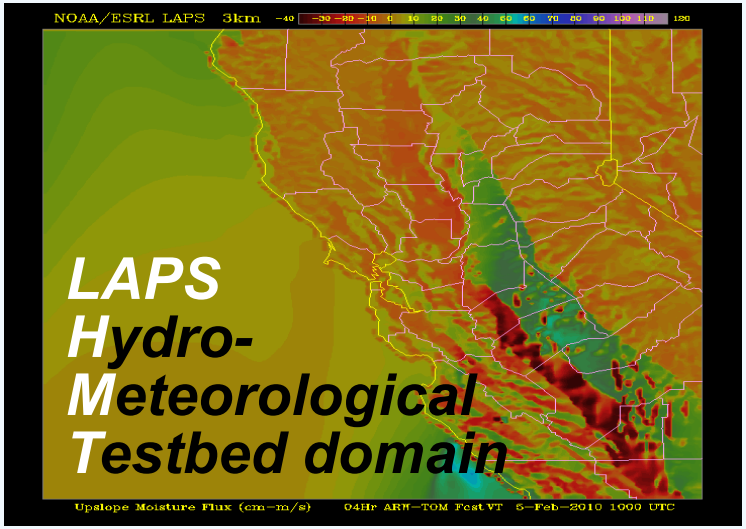
150+ users across government, academia, industry, and international sectors

On AWIPS, used in NWS offices for fire-weather, hydrology, short-term forecasting

Support for Hydrometeorological Testbed (HMT) over Western U.S.

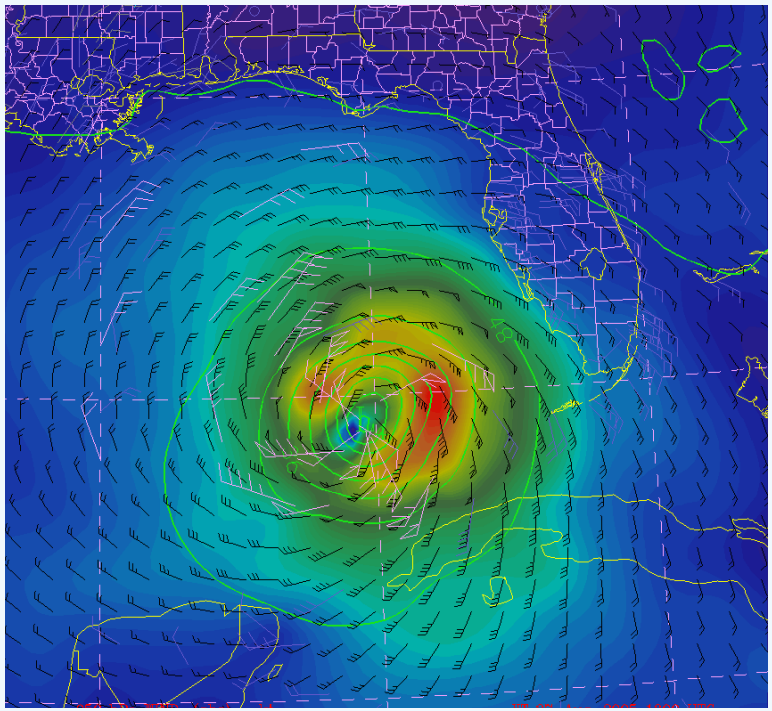
Future plans: AWIPS II, new data (polarimetric and airborne radar), new analysis every 15 min





Space-Time Mesoscale Analysis System

Sequential variational multigrid analysis for surface and 3-D applications



STMAS analysis of Hurricane Katrina
950-hPa wind speed and barbs

Variational successor to LAPS, same flow and data processing

Use of multigrid techniques for multiscale analysis problem

Experimental testing for hurricane and severe weather analysis

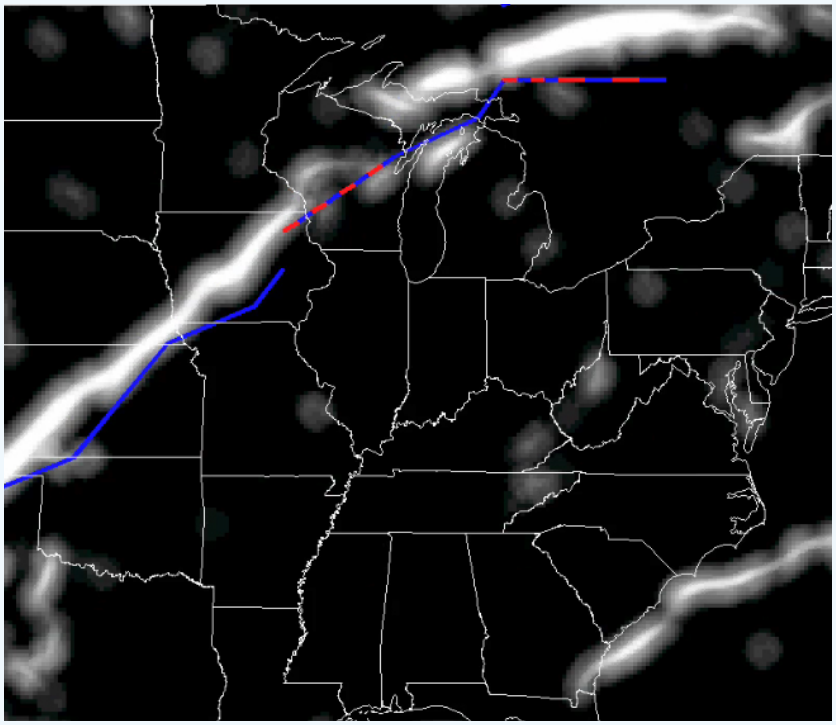
Space-Time Mesoscale Analysis System

Real-time applications and ongoing work

Real-time 2-D application using mesonet data every 15 minutes

15-min STMAS surface fields used for FAA/MIT boundary detection algorithm

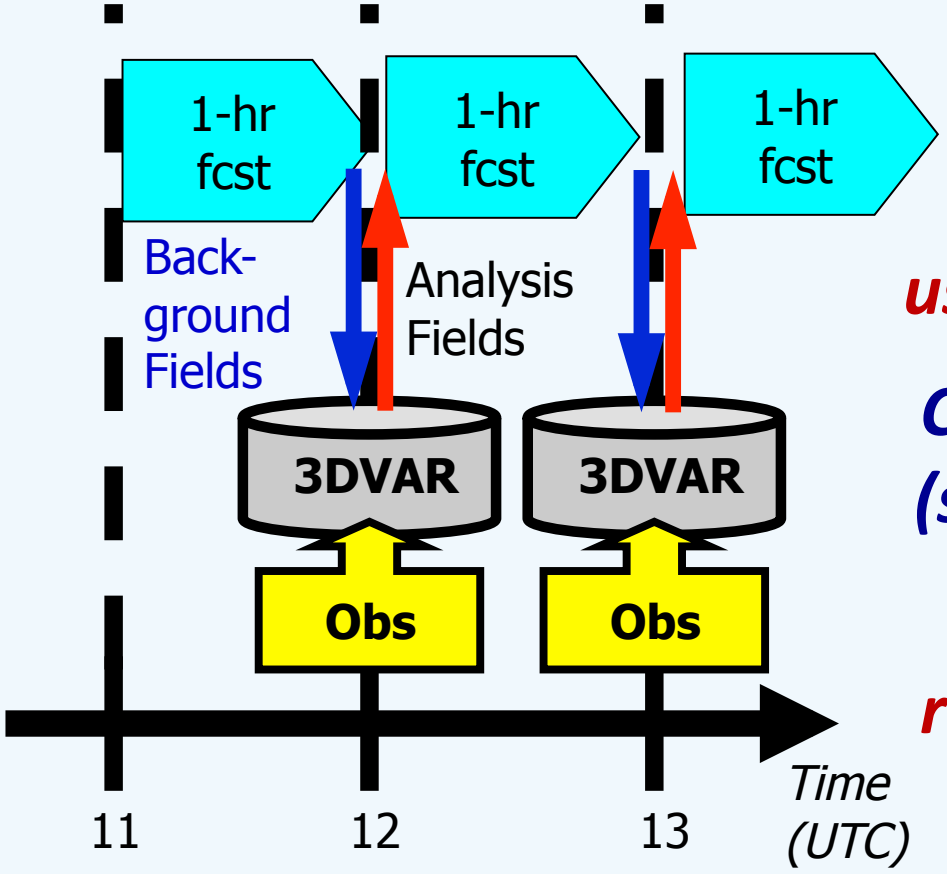
Testing 5-min update version and developing 4-D version



Frontal detection diagnostic applied to STMAS 15-min output field

Rapid Update Cycle 3DVAR

NCEP operational hourly updated system for aviation, severe weather, short-range needs



Isentropic analysis & model

Close fit to surface data, use of many observation types

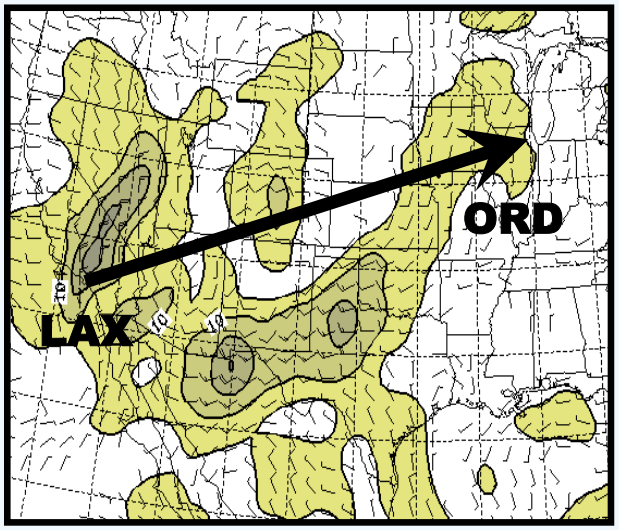
Cloud / hydrometeor analysis (satellite, surface, radar data)

Diabatic digital filter-based radar reflectivity assimilation

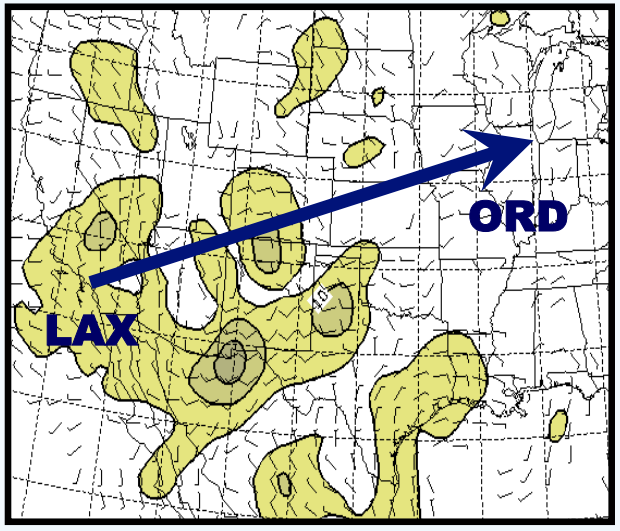
Benefits of Rapid Cycling NWP

Rapid update cycling improves short-range forecasts including upper-level winds

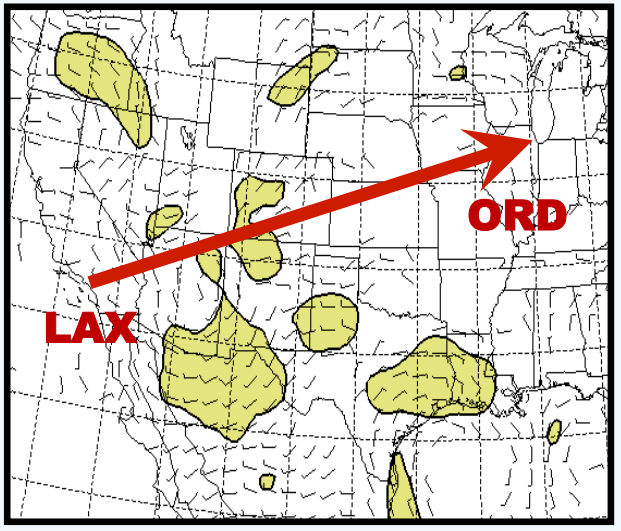
12-h fcst wind errors



6-h fcst wind errors



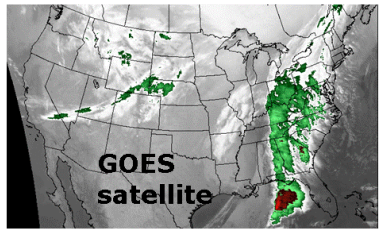
3-h fcst wind errors

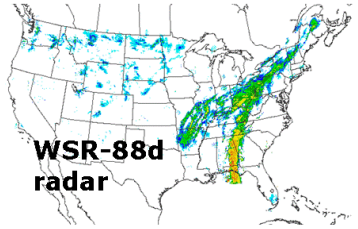


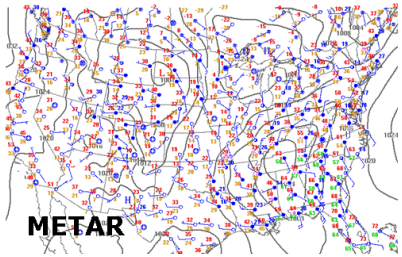
RUC 250-hPa wind forecast errors

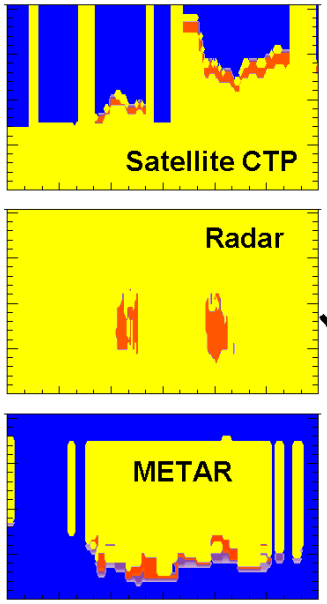
Cloud and Hydrometeor Analysis

Incremental adjustment based on information from multiple observation types

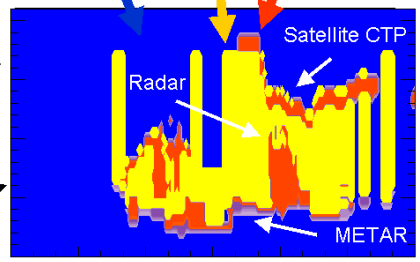


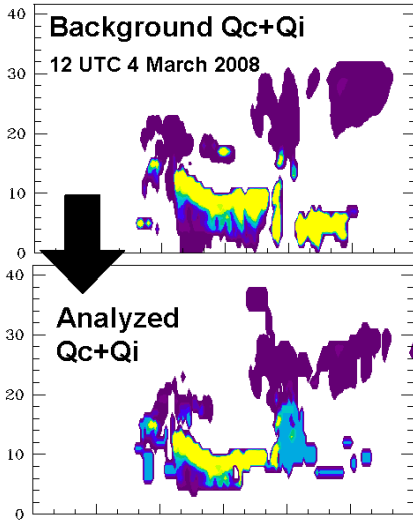






Cloud designation from observations





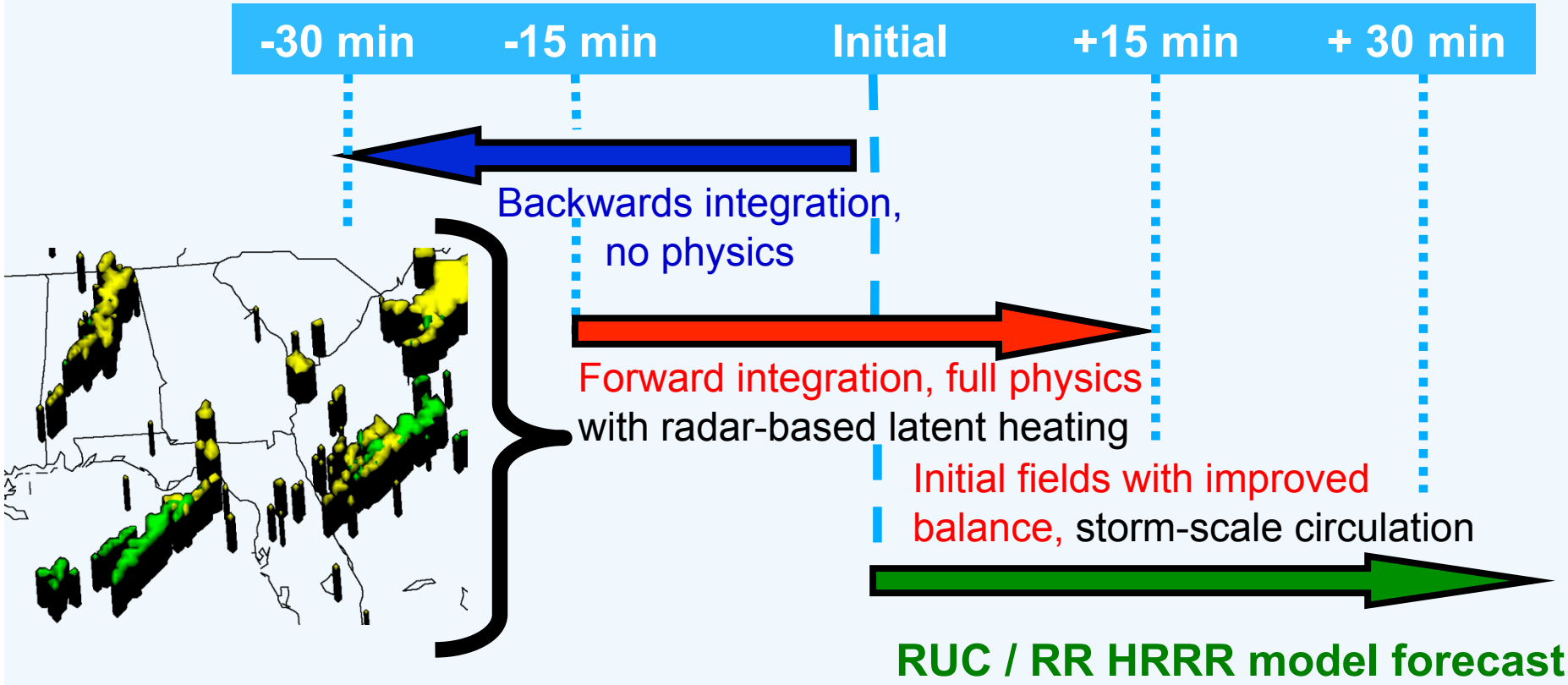
observations

data fusion

adjustment to background

Radar Reflectivity Assimilation

Digital filter-based reflectivity assimilation (radar-DFI) initializes ongoing precipitation regions



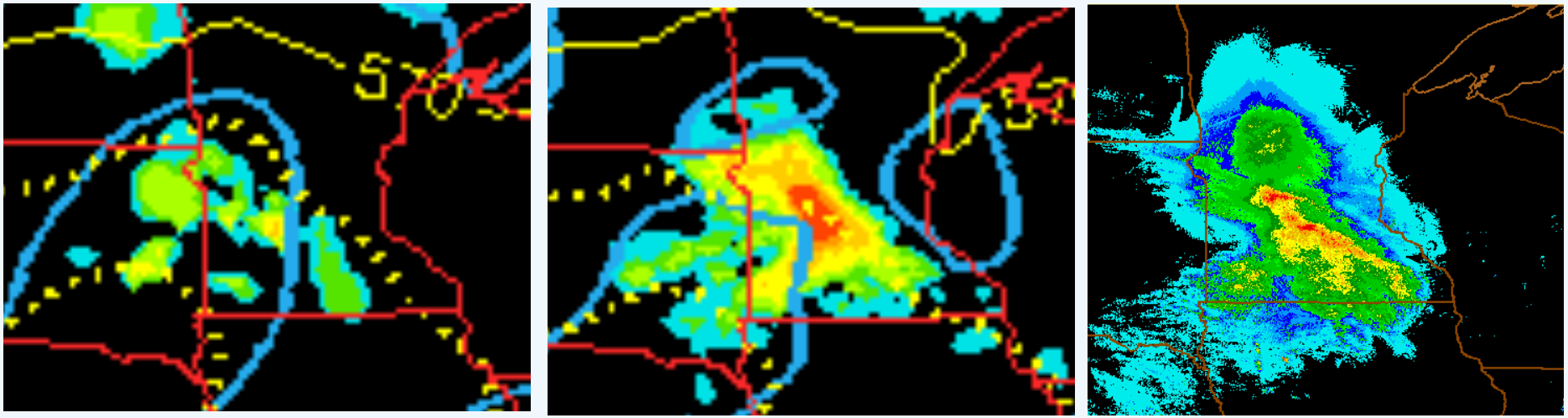
RUC Precipitation Forecasts

Digital filter-based reflectivity assimilation (radar-DFI) improves RUC precipitation forecasts

No radar assimilation

RUC radar assimilation

NSSL precip verification



RUC 3-h precipitation forecasts

15 UTC 31 July 2008

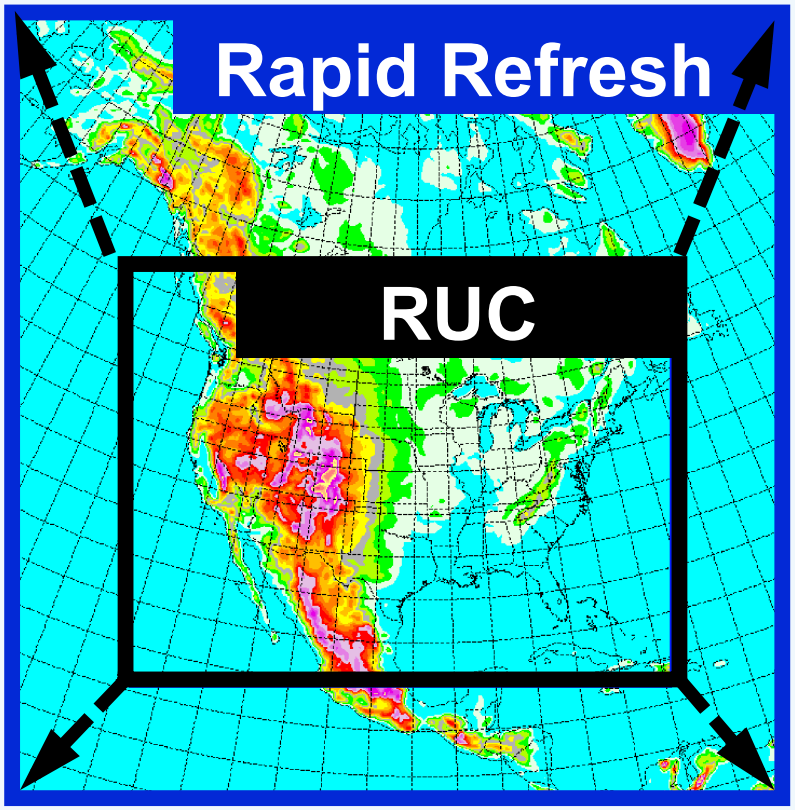
Rapid Refresh

Successor to RUC, final testing toward 2010 implementation at NCEP

ESRL use and enhancement of two community-based codes: WRF-ARW model and Gridpoint Statistical Interpolation (GSI)

Hourly cycled forecasts for all of North America including Alaska, Puerto Rico, and the Caribbean

Includes both cloud analysis and radar reflectivity assimilation



Rapid Refresh Benefits

Improved forecast skill over RUC

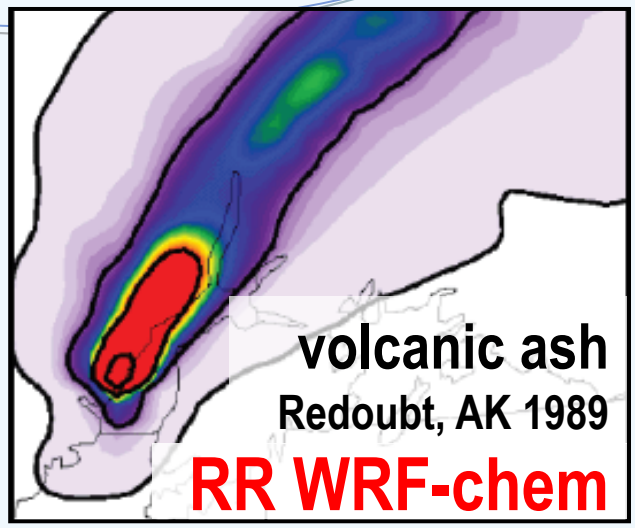
Detailed cloud analysis strongly improves ceiling and visibility fcsts

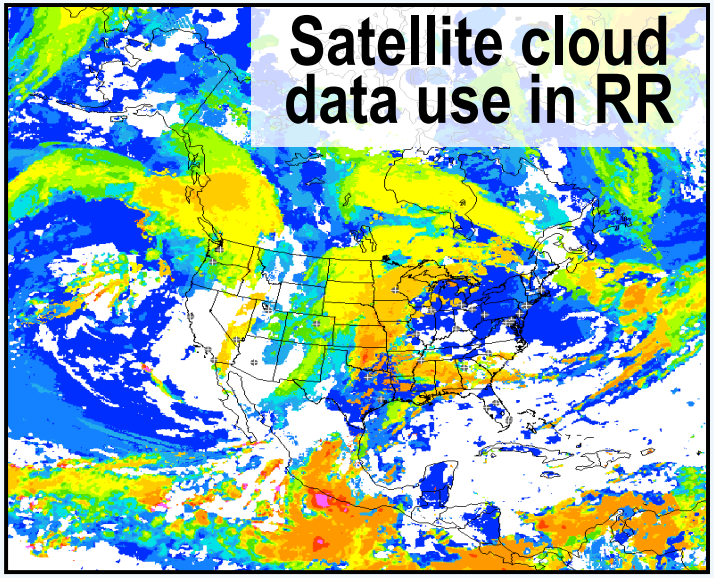
Use of radar & lightning data to initialize precipitation systems

Testing in-line chemistry and chemical DA for future RR

Operational implementation at NCEP expected 4th quarter 2010

Precursor to North American Rapid Refresh Ensemble (~2013)





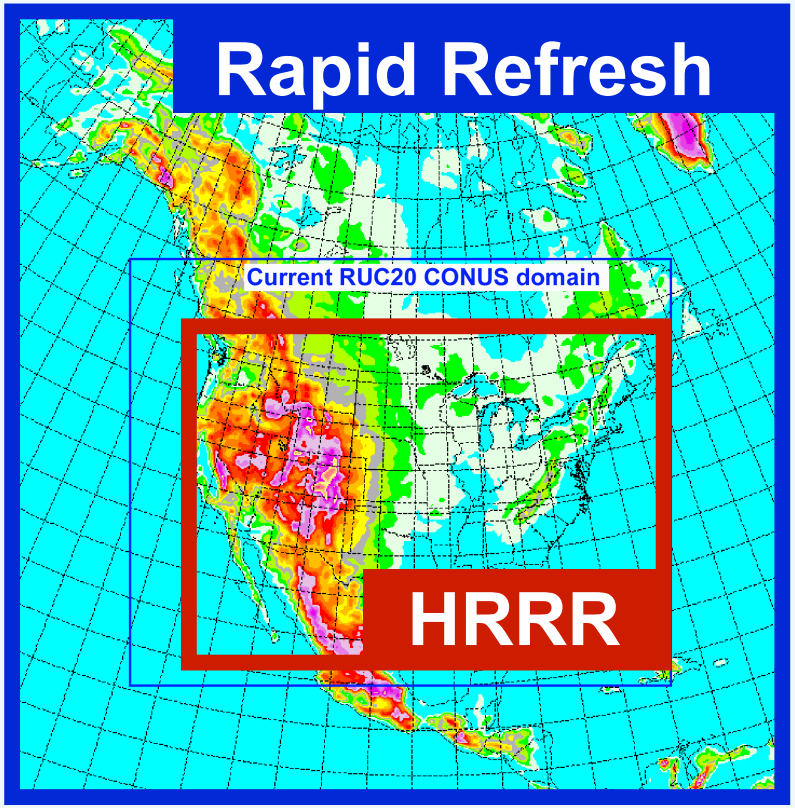
High-Resolution Rapid Refresh

Real-time experimental hourly updated 12-h forecast for 3-km CONUS domain

3-km grid-spacing → explicit prediction of thunderstorms

Improved prediction of terrain related and other mesoscale features (wind, clouds, precip)

HRRR runs as nest within RUC or Rapid Refresh and benefits from RUC / RR data assimilation



High-Resolution Rapid Refresh

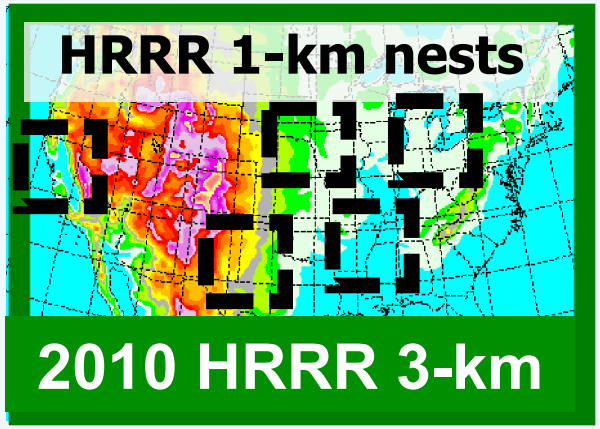
Real-time experimental hourly updated 12-h forecast for 3-km CONUS domain

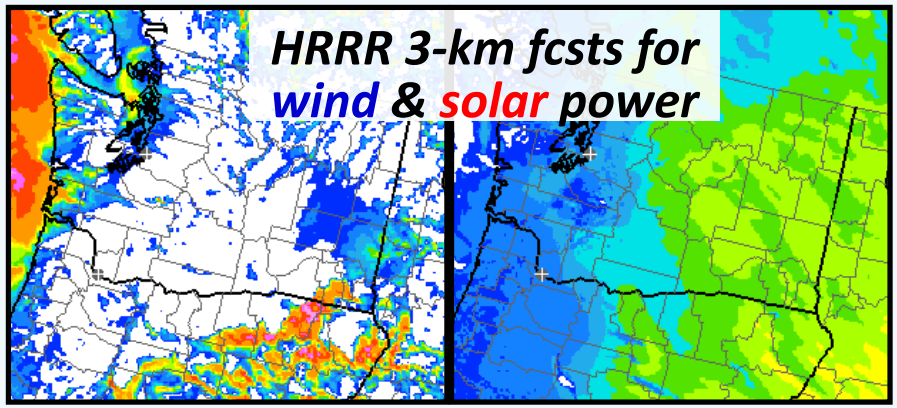
HRRR provides key convective guidance for NextGen aviation

HRRR essential component of Warn-on-Forecast development

HRRR provides guidance for renewable energy

Plans for 1-km HRRR nests, sub-hourly update cycling

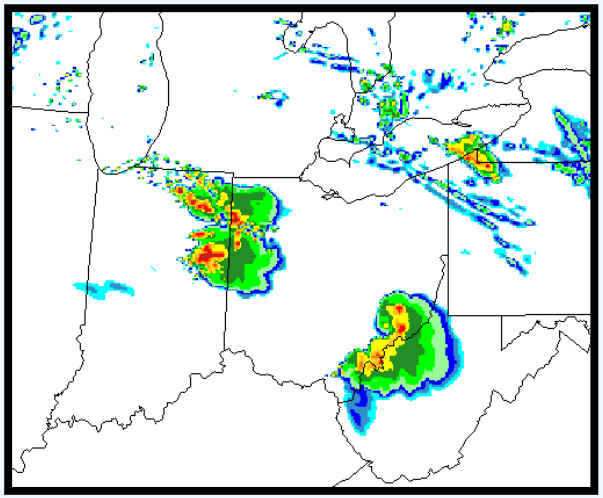




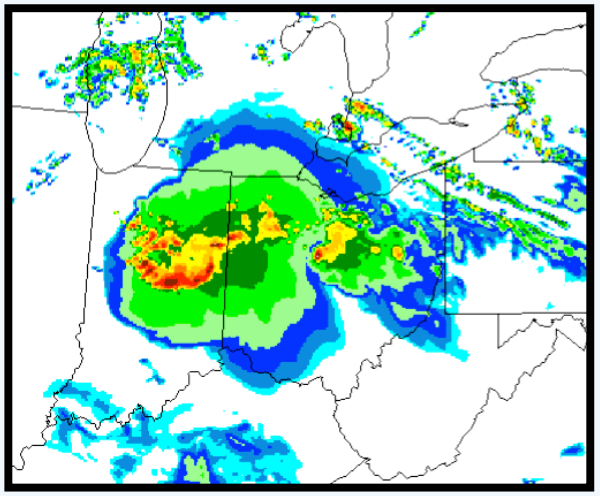
RUC radar assimilation helps HRRR

Digital filter-based reflectivity assimilation (radar-DFI) improves thunderstorm prediction

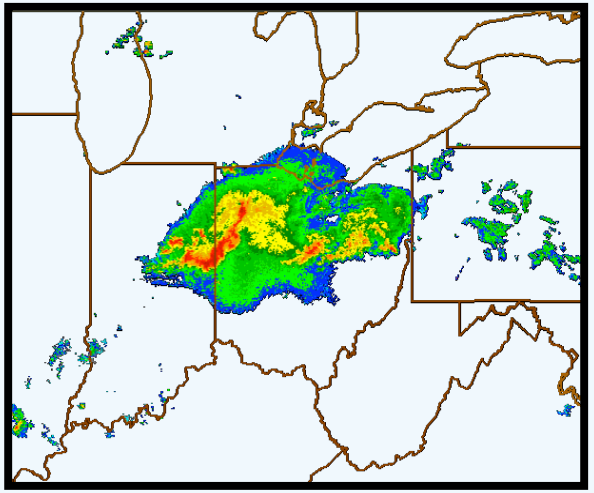
No radar assimilation



RUC radar assimilation



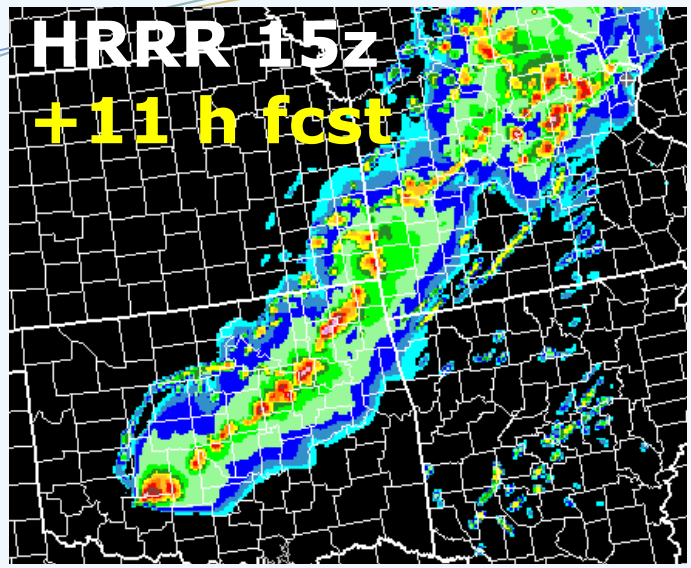
NSSL radar verification

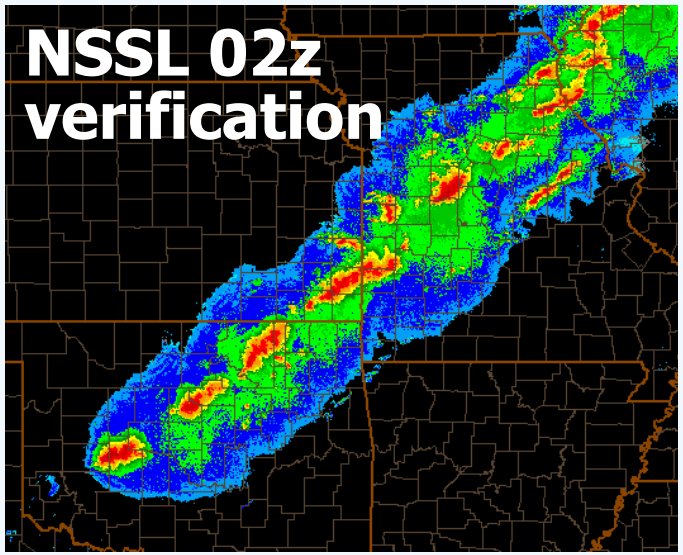


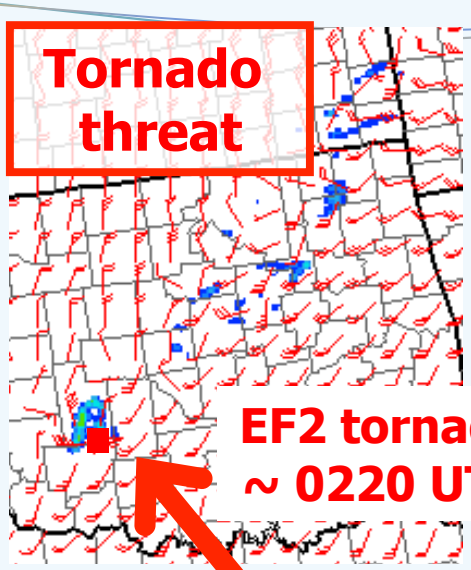
HRRR 6-h reflectivity forecasts

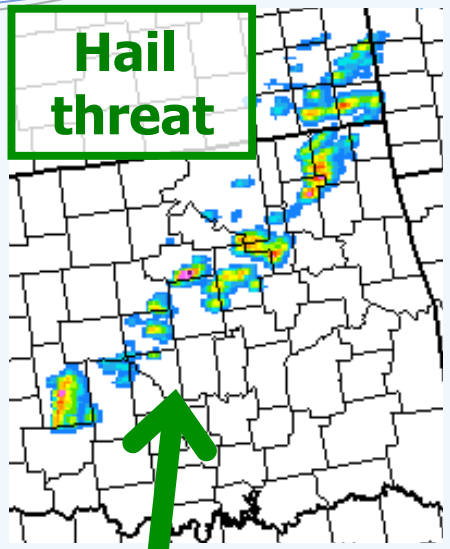
06 UTC 16 Aug. 2007

HRRR severe hazard guidance







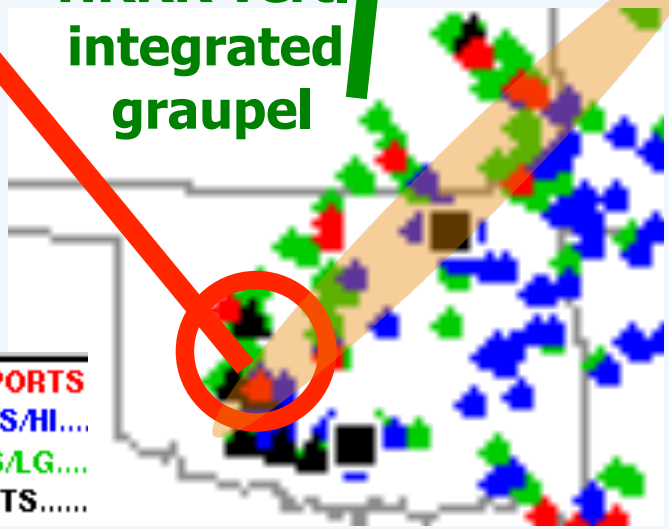


EF2 tornado
~ 0220 UTC

HRRR vert. integrated graupel

HRRR updraft helicity

Collaboration with NSSL

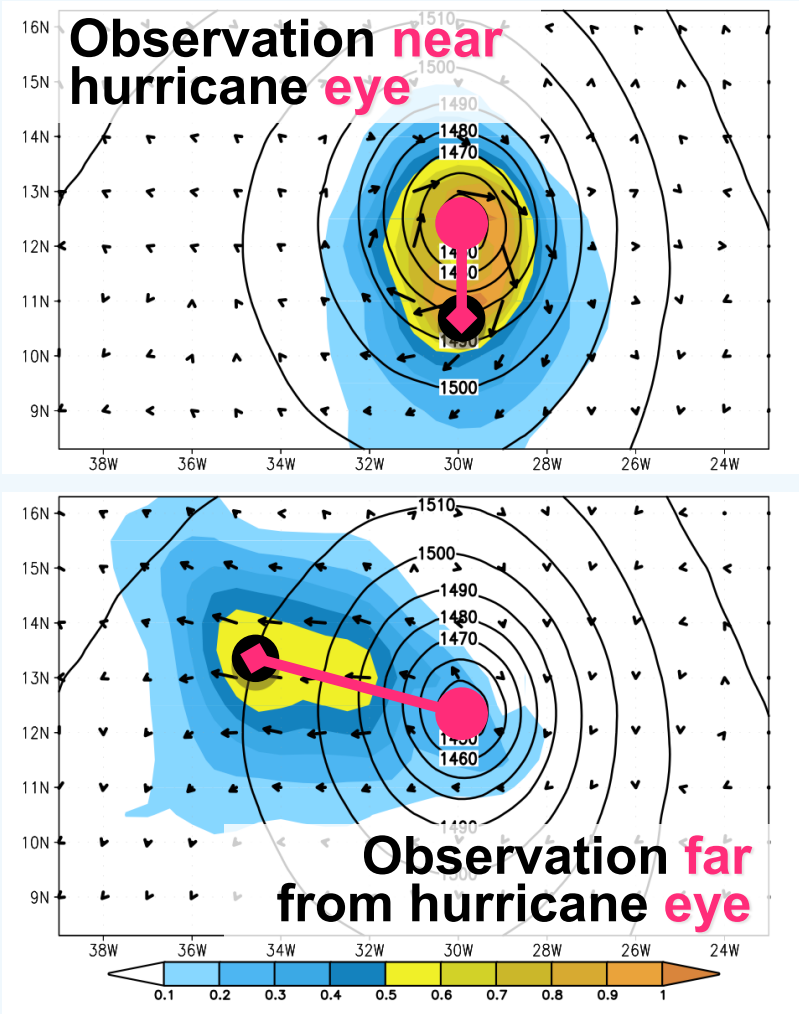


Recent Advances in Data Assimilation

Ensemble Kalman Filter (EnKF) – ***Improved forecast error correlation structure → better analysis increments***

Advantageous for analysis of mesoscale features (hurricanes, frontal bands, thunderstorms)

Better fit to observations and superior forecast skill



EnKF single observation increment examples

Global Ensemble Kalman Filter

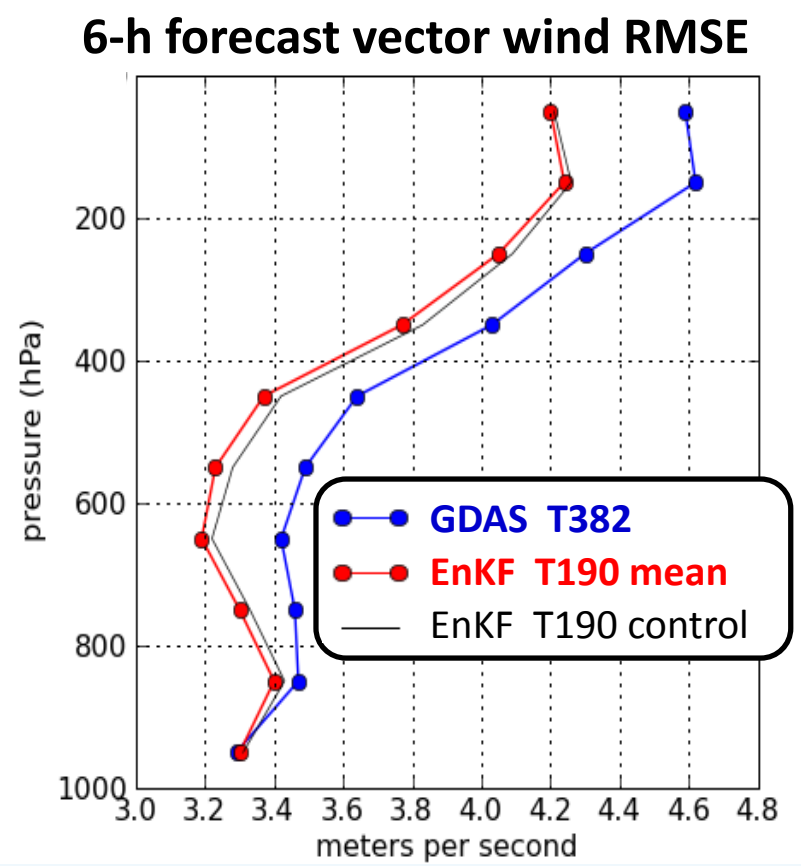
Improved 6-h forecast compared to GSI 3DVAR

ESRL testing EnKF with GFS and FIM, plans for RR

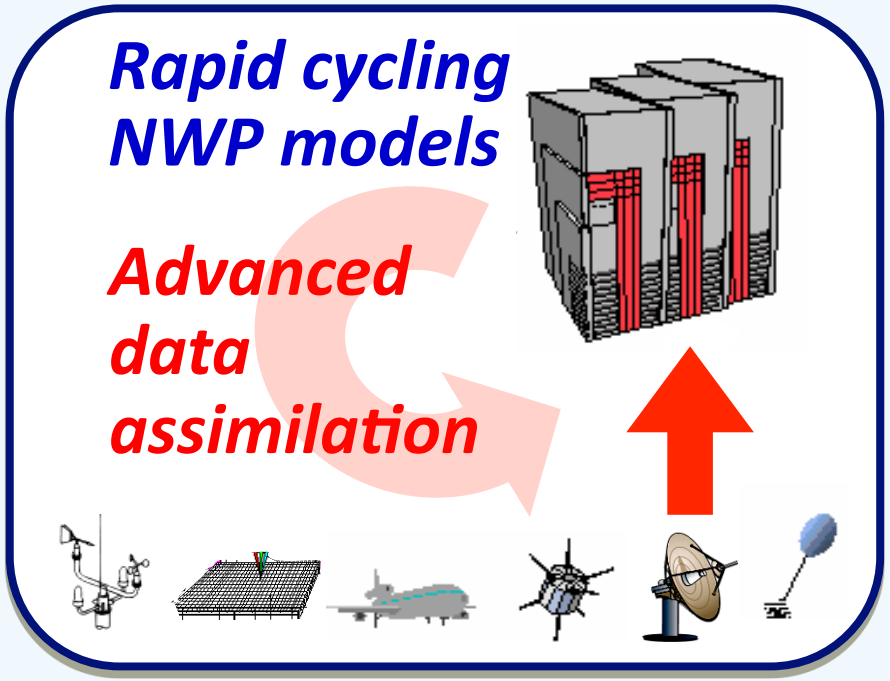
EnKF collaboration: ESRL, NCEP, GMAO, CAPS, AOML

EnKF development using GSI

Work toward possible hybrid EnKF implementation at NCEP



ESRL Advanced Data Assimilation and Rapid Cycling Numerical Weather Prediction



Continued development in collaboration with:
NCEP, JCSDA, AOML, NSSL, NCAR, AFWA, CAPS

Advanced techniques
radar-DFI, EnKF, hybrid

Novel use of observations for high impact weather

Radar, satellite, surface obs for aviation, severe weather, and energy applications

Accurate forecasts…
…global to local scales